Lawrence Livermore National Laboratory

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Laser Science & Technology

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Meter-Scale Gratings Delivered to Rutherford for Petawatt Laser Upgrade

LLNL recently completed the fabrication of meter-scale diffraction gratings for Rutherford Appleton Laboratory's (RAL) Vulcan Laser Petawatt Upgrade. RAL in the United Kingdom has been operating Vulcan at 100 TW, providing sub-picosecond pulses at intensities of 10^{19} W/cm^2 for the study of high-intensity laser/matter interactions. The upgrade (which is based on LLNL's Petawatt laser and scheduled for completion in 2002) will enable the compression of 500-J, 500-picosecond pulses for 1 petawatt (10^{15} W) of power and 10^{21} W/cm^2 at target.

The enabling components for achieving this ultrahigh power density are large-aperture diffraction gratings, which are only obtainable from LLNL. These gratings are optimized for high-efficiency and flat wavefront at the nominal 1053-nm use wavelength. These gold-overcoated plane gratings are patterned in photoresist using laser interference lithography, on optically polished substrates 94 cm in diameter with the top and bottom chords removed for a vertical aperture of 75 cm. The grating pattern is written on LLNL's large holographic exposure station, which utilizes two 110-cm-diameter F6 fused silica aspheric collimating lenses to provide a flat-wavefront exposure field at this aperture. Figure 1 shows LS&T's large-aperture diffractive optics production chamber, where the meter-scale diffractive gratings are produced.

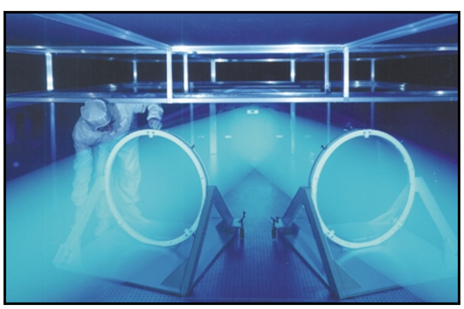

Figure 1. Large-aperture diffractive optics production chamber, where the meter-scale diffractive gratings are produced.

RAL has contracted with LLNL for several gratings over the years. The fabrication procedure is basically the same as that used for the original LLNL Petawatt gratings (see March 2000 *LS&T Program Update*), with the exception of recent improvements made to the exposure system to improve fringe stability during patterning of the grating. Briefly, the substrate is cleaned and then a layer of material is vacuum-deposited as an adhesion layer for the photoresist. A film of photoresist, ~250 nm, is applied by meniscus coating, and the substrate baked in a large convection oven to dry the resist. The blank is then mounted on the large interferometer table and allowed to stabilize for at least 24 h. The grating pattern is then written by exposing the resist film to interfering plane waves of 413-nm light from a Kr-ion laser. Exposure times are typically 10 minutes. During this time, the spatial location of the fringe pattern generated at 1480 lines/mm (675-nm period) must be held to within a small fraction of this period to maintain the intensity contrast in the exposure plane. Various methods are utilized to accomplish this, including vibration isolation, isothermal environmental control, and active fringe stabilization using a portion of the two exposure beams to provide a secondary interference pattern. A fringe detection/piezoelectric mirror system is used to control the path length of one of the beams to compensate for vibration drift. Following exposure, the latent image in the photoresist film is developed by contact with a base solution to convert it into a surface relief image.

The grating structure evolution is monitored with a probe laser during development to control the details of the groove shape. Following the development step, visual inspection for defects is done, and measurements of the diffraction efficiency of the photoresist grating are made to determine the spatial uniformity of the pattern. The grating is subsequently hard-baked, and then ~500 nm of gold is applied by vacuum e-beam evaporation. The grating is then subjected to full-aperture diffraction efficiency measurements at the use wavelength as well as wavefront measurements. If at any time of the process, specifications are not met or defects in the grating surface are identified, the gold and photoresist layers can be stripped off and the grating blank reprocessed without the need to repolish.

Figure 2 shows the full-aperture diffraction efficiency of two 94- × 75-cm gold-overcoated petawatt compressor gratings (measured at 1064 nm, 54° incidence angle) that meet specifications for delivery. Also shown is the footprint of the beam RAL researchers are to compress; 80 and 90% contours are also shown. The average diffraction efficiency in the beam footprint for these gratings is 92.8% and 93.8%, respectively, which represent the best uniformity we have been able to achieve to date at this scale. Figure 3 shows one of the gratings during wavefront testing at LLNL. The two large gratings, along with four smaller ones for the pulse stretcher and diagnostics, have been shipped to RAL.

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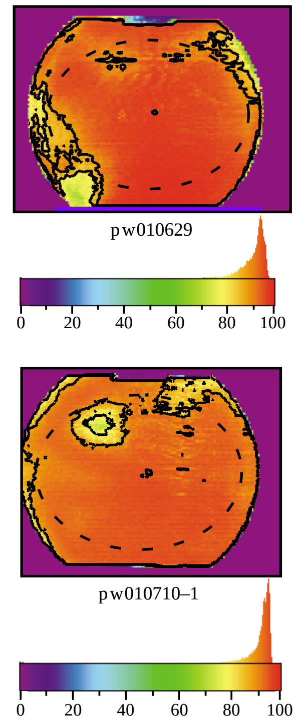

Figure 2. Full-aperture diffraction efficiency of two compressor gratings. Dashed lines show footprint of the compressed beam.

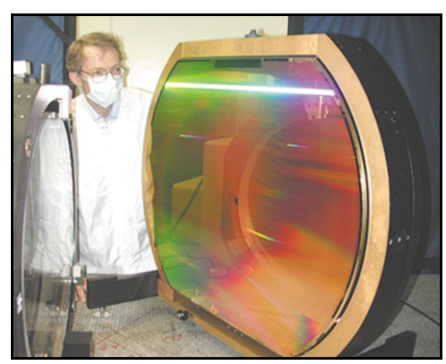

Figure 3. A meter-scale grating undergoing a wavefront test at LLNL.

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To get on the mailing list of the *LS&T Program Update*, send a request to Louann Arredondo, arredondo1@llnl.gov
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